"critical area" for any possible evaluation, dependent upon the particular field and the time of investigation.

Although this approach has not been pursued further, it is pregnant with suggestive thoughts for long-range planning. A group of experts might periodically re-view the status of achievements in a given field and indicate the direction of expected progress – an *a priori* mirror for deduction. Or, the sources of a published result of recognized scientific value might later be traced back through its citations *a posteriori.*

Some persons insist that scientists can seldom identify the significance of their work until the whole picture has been outlined. And yet in every article and every textbook written the author himself, not to mention the editor and the publisher, has already exercised some selection. Every time a grant is given to one person, several others have been automatically denied; a selection has been made. Paradoxically as the above project showed, scientists appear to be more willing (and able) to judge the possible value of a given research before it is done rather than afterwards.

Prospects for the Eradication of the Boll Weevil

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ABSTRACT

A large-scale pilot experiment to provide technology for the eradication of the boll weevil is described. A 10,000-acre cotton-growing area in southern Mississippi will be isolated and used for the integrated application of four previously tested control methods.

Everyone is familiar with the boll weevil (Fig. 1); if not from personal experience, certainly from legend. Dr. W. D. Hunter, one of the pioneer researchers on this insect, once described it as "the evil spirit that dwelleth amongst us." It might still be described in that manner. Any insect or other entity which has had as much economic impact as the boll weevil might be classified as evil. Several years ago the National Cotton Council estimated that the boll weevil had destroyed cotton valued at more than $10 billion, and it has been referred to many times as the $10-billion bug. It is still destroying cotton valued at about $200 million annually. This does not include the cost of controlling it, which is estimated at $50-$75 million annually.

Despite the fact that these tremendous losses have occurred and are still occurring, research has done a good job in making it possible for the cotton farmer to stay in business. Entomologists have developed control measures which have assured the farmer that he could make a profit in producing cotton. But it has been a hard and persistent fight. Calcium arsenate, of course, was the first insecticide which showed real promise in controlling the boll weevil. It was highly effective, but it had certain drawbacks and

Anthonomus grandis Boh. (Coleoptera: Curculionidae).

was far from a panacea. Then in the mid-40's, the organics came along (benzene hexachloride and toxaphene first), and these were followed by a long list of chlorinated hydrocarbons, many of which were highly effective. It looked like we were really in business, but suddenly in 1955 we realized that something had gone wrong. We were not getting control. The insect had outsmarted us and had developed a high degree of resistance to these insecticides. We were not wholly unprepared, however, because we had already experimented with some of the organophosphorus insecticides developed by industry and found them effective at lower dosages than the chlorinated hydrocarbons. In time, methyl parathion became the most widely used insecticide for boll weevil control, and it enjoys that position today.

So, up to this point we have managed to live with the boll weevil, but we have not solved the problem, which is as vexing today as it was 48 years ago when the weevil had completed its march eastward from Texas to the Atlantic. As for most of our insects, our research to date has not been designed to solve the problem–merely to learn how to live with it. Our technology has been insufficient to do anything else. But we have gradually added to our know-how, and perhaps we are arriving at a threshold where we can do something about attaining a solution.

We think we are about at that point in our research now, and we are making plans to demonstrate the feasibility of eradicating the boll weevil. The following is a brief description of the technology which we propose to use in accomplishing this.

First of all, it should be understood that the proposed effort is merely to determine if our present technology is at a level to make eradication feasible–it is not an attempt at eradication other than on an experimental area. Last summer Dr. E. F. Knipling, Director of the Entomology Research Division, was chairman of a special committee appointed by the National Cotton Council to select an area in the boll weevil belt and make recommendations concerning a pilot eradication experiment. The committee visited several locations from the Carolinas to Texas and finally decided on an area in South Mississippi as the core area, with the adjacent treated area extending into southeastern Louisiana and southwestern Alabama. The core area–that where eradication hopefully will be demonstrated – is approximately in the center of a circle 150 miles in diameter which contains approximately 75,000 acres of cotton. Hopefully, funds will be made available in time to initiate this pilot eradication experiment (remember, it is only an experiment) in the Fall of 1971. Essentially the plan consists of 4 phases, as follows:

Fig. 1. – The boll weevil – the "ten-billion-dollar bug" (x7).

- A reproductive-diapause control program carried out in the fall to reduce the overwintering boll weevil population to an extremely low level.

- The use of sex pheromone traps in the spring to lure and capture a high percentage of the surviving boll weevil population.

- One insecticide application just as the plants begin to fruit to kill any weevils that may have escaped the pheromone traps.
- Release of sterile male boll weevils to complete the job.

The reproductive-diapause control program has been amply demonstrated in several States to be highly effective in reducing the number of weevils entering hibernation in the fall. A diapause control program was developed soon after Brazzel and Newsom (1959) discovered that in order to survive the winter the boll weevil had to enter a state of diapause in the fall, and in order to attain a state of diapause it had to feed for a considerable time after emergence. This period of feeding essential to diapause often took place after all insecticide applications had been made to protect the crop. Consequently, feeding was uninhibited, and large numbers of weevils were able to attain the diapause condition before frost and to enter hibernation in a state for adequate winter survival. Several investigators, among them one of the discoverers of diapause Brazzel (1959). Brazzel *et al* (1961), and Lloyd *et al,* (1964, 1966), theorized that if insecticide applications were made following crop maturity and before frost, most of the diapausing population would be killed. They determined that 3 to 4 insecticide applications applied at 10-day intervals beginning in October would reduce the overwintering population by approximately 90% and that natural winter mortality would further reduce the remaining population by another 90%. This meant that not more than 1% of the original diapausing population would survive the winter and emerge into the fields in the spring. Large-scale community-wide tests demonstrated that this program would save several applications of insecticides in the spring, but generally the population built up during mid- and late-season to the level where insecticides were required.

Knipling (1968) studied the results of several of the large-scale tests and as a result proposed a reproductive-diapause control program. He reasoned that a tremendous population of weevils built up after normal insecticide applications had ceased and that, even though the diapause control program might reduce the diapausing population by 90%, enough weevils were left to develop a damaging infestation under favorable conditions before the next crop was made. He then theorized that if the last reproductive generation was destroyed, there would be fewer individuals left to enter diapause, and that if the diapause control was then undertaken, the population left to enter hibernation would be at an extremely low level. He proposed that the normal control program be continued during September by applying 7 additional applications scheduled to limit reproduction by the last reproducing generation and to destroy most of the weevils remaining in the field. This program was tried at several locations in Texas and Mississippi–it essentially confirmed the theoretical calculations showing the benefits of the reproduction-diapause schedule of treatments. Where a large enough area was treated, no economic damage was caused by the boll weevil until the crop was made.

Thus, the reproductive-diapause control program has been amply demonstrated to reduce the overwintering population of boll weevils to an extremely low level and therefore is an important part of the technology to be employed in the proposed eradication experiment. Every acre of cotton within the 10,000-acre core area and within a 25-mile radius will receive a full reproductive-diapause control program consisting of 7 applications of insecticides in the late summer and fall preceding the eradication attempt. Cotton up to a 75-mile radius exclusive of the core area will be treated with varying numbers of treatments to suppress the populations and reduce possible movement into the center test area.

The boll weevil sex pheromone produced by the male has recently been isolated, identified, and synthesized. It attracts both females and males and can therefore be considered both a sex and aggregating pheromone. It has been demonstrated in large-scale field tests (Hardee, *et al.*, in press) to be highly effective in attracting weevils which have emerged from hibernation in the spring of the year. Male weevils were confined in individual small screen cells attached to a sticky board wing trap (Fig. 2). Five male weevils were confined in individual cells and supplied with food—either a fruiting bud, young cotton boll, seedling cotton, or a synthetic diet plug. Males do not produce the pheromone until they have fed. The results with these traps have been nothing less than phenomenal. Weevils have been taken in the traps more than 25 miles from the nearest cotton. We don't know what percentage of the overwintered population was actually trapped, but in a large-scale test conducted in Monroe County, Miss., in 1969 enough were trapped in an area where most of the cotton received a reproduction-diapause treatment schedule that no insecticide applications were required to produce a crop on farms where the fall treatments were carried out on schedule!

The synthetic pheromone has been used in limited field tests which show that traps baited with the synthetic were comparable in effectiveness to traps baited with the male weevils. During January 1970, tests conducted in a half-acre screen cage in Iguala, Mexico showed that the traps baited with the synthetic material were equally as effective as traps baited with males for 4 days, the length of the test. The traps with the synthetic might have been effective for a longer period, and we hope that it can be formulated so that it will be effective for a week or longer. It is currently formulated in pellets containing a nylon resin on attapulgus clay plus a small amount of antioxidant [Tenox]. Bids received for commercial production of the first batch indicated each pellet would cost 3.3 cents; we expect that this cost will be greatly reduced—to 1 cent—when production is underway. The current concentration is 100,000 male equivalents per pellet; we hope that this may be reduced to at least 25,000 male equivalents. If this pellet is effective for a week, one can see that the cost of the synthetic material will be very low. The cost of the trap is about 50 cents and the "Stickem" is not a high-cost item.

So the second phase of the pilot experiment will consist of the use of sex pheromone traps placed in and around the fields at about the time cotton is planted in the spring. We don't know yet exactly how many traps may be required per acre, but there is some indication that one per acre may be sufficient. Large-scale tests are planned this spring to yield further information on this and several other phases of the trapping program, including trap design.

Fig. 2. – Sticky board wing trap used to entrap boll weevils lured by the male sex pheromone. Five virgin male weevils are confined in separate screen cages with food as shown in top center. The synthetic pheromone will replace the male weevils.

Step 3 in the pilot eradication experiment is the use of one application of a conventional insecticide to every acre of cotton in the experimental area, including the 10,000-acre core area and the 75,000-acre buffer area. This application will be made just as the cotton begins to fruit and is designed as a precautionary measure to kill any weevils which may have survived the traps.

The final step in the pilot eradication experiment is the release of sterile male weevils to mate with any females that escaped the pheromone traps and the single insecticide treatment, or to mate with females that emerge from hibernation after cotton has begun fruiting. Hopefully, the sterile males will further suppress reproduction by overwintered survivors, but they are also being counted upon to prevent or limit successful reproduction by any F_1, F_2, and F_3 boll weevils that may be produced. The question that is probably uppermost in the minds of many who are concerned with this problem is, "Do we have a competitive sterile male?" There is a difference of opinion among our scientists about this. Some think that we do have, but others are not so sure that we have the type of sterilization procedure desired.

Efforts have been concentrated on chemicals that will effectively sterilize the boll weevil. Sterilization can be accomplished by radiation but the treatment is so drastic that the males are not very competitive, and they generally die within a week after receiving a sterilizing dosage, so we have been forced to look for a chemosterilant. The most promising one to date is busulfan [Myleran]. The emerging males are fed for 5 days on a diet containing 0.1% of this compound. At the end of this time, the males are generally sterile for life, but some may regain their fertility. However, even if 10% of the males regained their fertility, and if the ratio of treated to normal males for the greatly reduced natural population is 100:1, the sterilized males should achieve a high degree of suppression. It is not essential that the boll weevils be eradicated immediately. The whole concept of the suppression methods to be integrated is to keep the boll weevil population at a low enough level that it cannot survive. If the boll weevils can be held down to a virtual extinction level during the first season, the additional suppressive measures the next fall, together with natural winter mortality, should lead to elimination of the weevil by or during the second year. Another suppression feature that will be built into the system is the use of boll weevils that cannot diapause normally. The ability to diapause has been largely bred out of the strain that will be sterilized and released.

Thus, there are improvements that we hope can be made in the various suppression techniques to be used, but there is optimism that we already have the means to eliminate boll weevil populations. The pilot test is proposed to see if eradication is in fact technically and operationally feasible.

Such are the plans which have been developed to conduct a pilot boll weevil eradication experiment. One alternative, or a supplement to those described, might be mentioned. We have been working with systemic insecticides for cotton insect control since 1948 and have had some successes. During the past 3 years we have been much encouraged over results we have gotten with aldicarb [Temik] against the boll weevil. In a large scale test conducted in West Texas last summer, a combination of reproductive-diapause treatments applied in the fall of 1968, the use of the pheromone traps in the spring, and a systemic treatment consisting of one pound of aldicarb at planting plus two pounds applied as a sidedress treatment at squaring, apparently resulted in eradication of the weevil until migration occurred from the outside. We believe that aldicarb could be used in an eradication effort, and extensive tests are planned with it this year–it has been registered for use on cotton, and it may find an important place in cotton insect control. The principal disadvantage to its use is that it kills most parasites and predators in the cotton field, usually resulting in a heavy bollworm attack. But if for any reason the other suppressive measures are not capable of eliminating the reduced population, we believe that we could use aldicarb to do the same job–that is, to mop up on any remaining weevils that might survive the reproductive-diapause treatment followed by the pheromone traps and the one application of a conventional insecticide.

We predict that this pilot eradication experiment, designed to provide adequate technology to eradicate the boll weevil, will be successful.

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